Design a Mission: Planetarium Handbook

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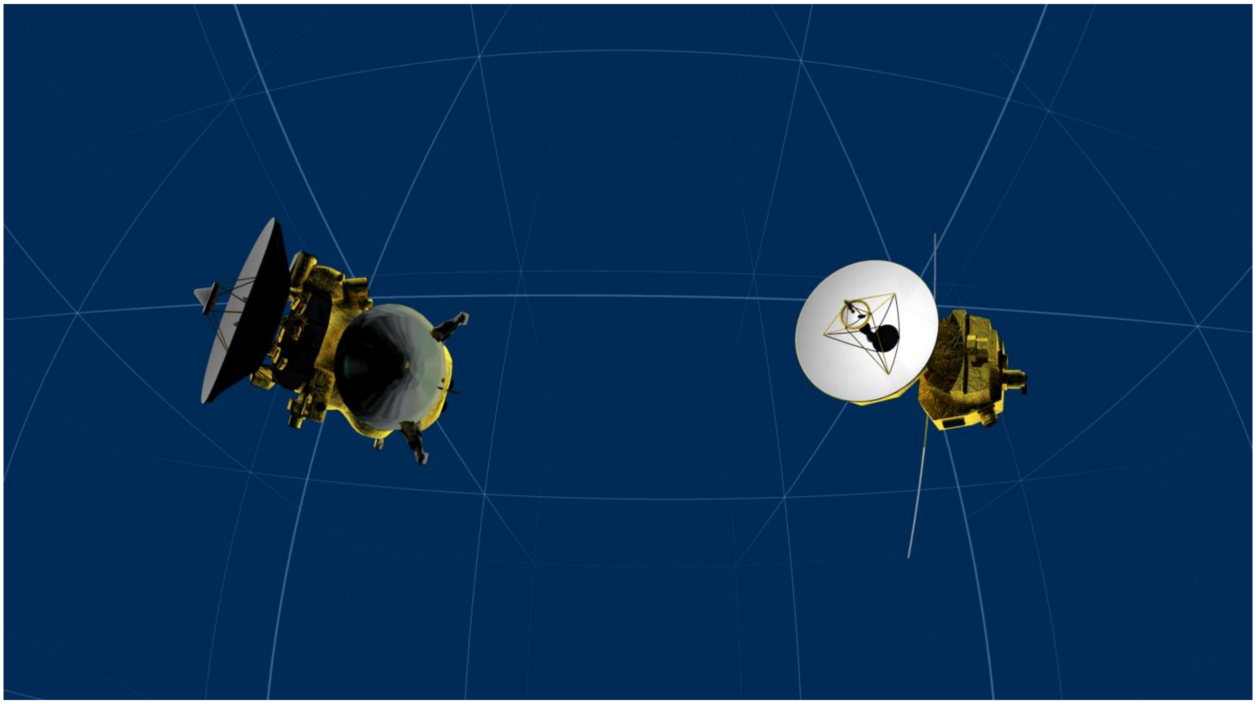
The guide and its contents were created to supplement the fulldome planetarium show: *From Dream to Discovery: Inside NASA*, produced by the Charles Hayden Planetarium at the Museum of Science, Boston. Additional information about the show can be found at: www.mos.org/fulldome.

Questions regarding the content of this guide can be directed to Amanda Thompson (athompson@mos.org) or Talia Sepersky (tsepersky@mos.org). Questions regarding the planetarium show can be directed to Dani LeBlanc (dleblanc@mos.org).



Screenshot from the “Design a Mission” interactive. Image © Museum of Science, Boston.

Museum of Science.

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Introduction

Design a Mission is an educational module designed for use in the planetarium for both the general public and for school groups in grades 5-12. The module consists of this handbook and a series of fulldome video clips. The video clips can be downloaded at *www.mos.org/fulldome*.

This module is designed to be fully interactive and presenter-led, allowing the audience to make a series of choices inspired by the Engineering Design Process. Depending on the choices they make, the mission they are designing can end in success or failure, and there are video clips to support each decision in the process.

Please note, though this module is designed to supplement the planetarium show *From Dream to Discovery: Inside NASA,* it can be used independently of the show and adapted for any live presentation.

Within this handbook you will find information regarding:

- **Progression of the Activity –** A general outline for the progression of the program, along with audience prompts and general background required to inform each choice.

- **Images Used for Mission Success** – A list of images with credits and brief descriptions. These images are the ones used for each mission path that yields success.

- **Images of Mission Failure** – A list of images with credits and brief descriptions that are shown in conjunction with a group's failure of the mission.

- **Video Clip List** – This is a breakdown of all of the clips that go with this program, for all of the possible scenarios.

- **Links to Outside Activities** – A list of links to outside resources for further background or activities.

Progression of the Activity

The "Design a Mission" activity relies heavily on the information that the presenter provides to the audience before they make the choices that advance the program. How much information you provide and how deep you choose to delve into the material might depend on 1) the level of your audience (i.e., 5th graders vs. high schoolers) and 2) the amount of time you have. A full run-through of the activity should take approximately 20 to 25 minutes.

Items that are underlined below indicate critical information the audience needs to inform their decisions. Suggested questions to engage the audience are noted *in italics* below. These questions are not an exhaustive list, nor are the possible answers listed in parentheses immediately following.

Introduction to audience

Visuals: For this section, visuals are not provided and are up to you. We suggest some dim lighting so the audience can still see you as you present the introduction (and so they can get the idea that a real person is facilitating this activity).

Interaction: The idea is that the audience is designing a fictional space mission to study Mars or Saturn. One suggestion for setting the stage for the activity is telling the audience that they have been chosen as the engineering team for the next unmanned mission to one of these planets. Specifically, their mission's goal is to design a spacecraft that will be searching for evidence of water (past or present) in the Mars or Saturn systems. Ask the audience:

> *Why do you think Mars is a good target to study for water?* (Possible answers: It's close, it's known to have water in the past)
> *Why do you think Saturn is a good target to study for water?* (Possible answers: Ice in the rings, ice/liquid water on the moons)
> *Why are we looking for water anyway?* (Possible answer: looking for conditions of life)

You can either simply tell them that most of the spacecraft body has already been assembled, or you might ask them:

> *What kinds of parts would a spacecraft have?* (Possible answers: an antenna, navigation computers, a camera, etc.)

As part of their engineering duties, they must make several important decisions about the design and capabilities of their spacecraft. This leads us to…

> The method of voting: We suggest voting by applause, as it is most likely that you will be conducting this activity in the dark environment of the planetarium. If you have another method in place to tally voting (ex: electronic), that works, too!

After introducing that they will be flying to a planet and that they must design a spacecraft to look for evidence of water, you can now move on to the first choice:

Choice #1: Mars vs. Saturn
<u>Visuals</u>: For this section, there is one video clip (Clip 00). This clip will have a blue background with gridded squares (intended to look like a 3D blueprint) with both planets slowly rotating. They will not be truly to scale, which might be worth pointing out to the audience since Mars will have to be inflated quite a bit to be distinguishable next to Saturn. The clip is approximately 40 seconds, but is designed to be looped.

<u>Interaction</u>: This choice will determine their mission's destination. Because it may not be immediately obvious that you can find any evidence of water at either place, it might be worth reminding them that water can exist as a liquid, solid, or gas.

> *Is water common in the solar system?* (Yes, very common, though liquid water is less common)
> *What kind of water do you think you are most likely to find at Mars or Saturn?* (Ice)
> *If we find evidence of water, does that prove there is other life?* (No)
> *Could liquid water exist anywhere besides the surface?* (Yes, below the surface)

Once they are thinking about the very different possibilities for water on each planet, ask them to decide:

A) Mars? OR
B) Saturn?

Choice #2: Lander vs. Orbiter
<u>Visuals</u>: For this section, there is one video clip (Clip 01). This clip will have the "blueprint" background from before, this time with two slowly rotating spacecraft bodies. One spacecraft will have a conical attachment that is meant to be the lander. The other (the orbiter) will be smaller and will not have the attachment. The clip is approximately 40 seconds, but is designed to be looped.

<u>Interaction</u>: This particular choice will determine how their spacecraft will collect its evidence. A good lead-in might be to ask them what they think the different choices will accomplish. For example:

> *How can a lander look for water?* (Drill, drive around, look for fossils, look for ice)
> *How can an orbiter look for water?* (Make a map, look for rivers, look for ice, look at the whole planet)
> *What are the drawbacks of a lander?* (You cannot see the entire planet; landing is dangerous)
> *What are the drawbacks of an orbiter?* (You cannot take samples)

Once you've got them thinking about each type of mission, ask them to decide:

A) Land? OR
B) Orbit?

Choice #3: Solar vs. Nuclear
<u>Visuals:</u> For this section, there are two potential video clips (Clips 02a and 02b). The video clip will be different depending on whether they chose a lander or an orbiter in the previous section. However, both clips are similar to the last section, where two spacecraft bodies (either both landers or both

orbiters, depending on the decision) are slowly rotating overhead in 3D blueprint space. One body has solar panels attached, the other does not, and is intended to be the nuclear option.

<u>Interaction</u>: This particular choice will determine how their spacecraft will receive its power throughout the mission. Before you ask them their opinions about the different power supplies, it is important to give them sufficient background information for how the two options work (through testing, we found people were really unsure about how nuclear power even worked). We suggest starting with solar power, as they're bound to have seen examples of it before. Some beginning questions might be:

> *Where have you seen solar power used?* (On houses; calculators; the space station)
> *How do you think solar power works?* (It turns sunlight into energy)

Building on what they seem to already know about solar power (or what they do not know), explain that solar power relies on panels made of semi-conductive material, which collects the energy of the Sun and converts it to electricity. Ask them:

> *What are the benefits of solar power?* ((1) Cheap – Solar power technology is common; 2) Well tested – engineers know how solar panels work and have an idea of what to expect; 3) Unlimited - the most important resource (the Sun) is free)

There are a lot of positives, so ask them to consider any drawbacks to solar power. For example:

> *Are there some places you cannot use solar power?* (Far from the Sun, behind planets/in shadow, in bad weather)

Additionally, solar power is not very efficient. Some energy is lost in the process, so the panels do not harness 100% of the Sun's energy. Also, the farther the mission travels from the Sun, the less light there is to capture. The farthest it is feasible to use solar panels with current technology is Jupiter.

When it comes to nuclear power, it is important to remind them that it's not a nuclear power plant, like they might have seen on TV. In this case, it is often a very small (i.e., the size of a large marshmallow) pellet of radioactive material that is slowly decaying. As the radioactive material (in many cases plutonium-238) decays, it creates heat, which is then used to create electricity (for more information, look up the "Seebeck effect"). Having a general idea of how it works, ask audiences:

> *When might nuclear power be a good option?* (Missions far from the Sun, harsh environments with unpredictable weather, long missions, small spacecraft)
> *What are some drawbacks to nuclear power?* (It's expensive, small supply)

At this point, they should have a good enough grasp of the information to decide:

A) Solar? OR
B) Nuclear?

Mission Outcomes

Visuals: For this section, there are nine potential video clips (listed in more detail below). The one you play will depend on the previous three choices. Each clip, with the exception of Clip 04, is a long animation running approximately 4-5 minutes. Clip 04 will bring up a series of still images around the dome and will run approximately 30-45 seconds.

Clip M03a – Mars + Land + Solar: Take off Earth, view Earth from space. The spacecraft will be visible as we fly to Mars. Once we arrive we will slowly orbit Mars, at which point the lander will detach and approach the surface. This will crossfade to the Curiosity fulldome landing video originally created by JPL, following the lander all the way to the surface. At that point the video will pause (with a panorama of Mars visible), and 3 still images will fade up at various orientations on the dome, showing examples of scientific data "collected" from the mission (these are images chosen from some actual Mars missions, and are explained in more detail on pages 9 and 10). This mission is considered a success.

Clip M03b – Mars + Land + Nuclear: Same as Clip M03a, but using the spacecraft body without solar panels. This mission is considered a success.

Clip M03c – Mars + Orbit + Solar : Take off Earth, view Earth from space. The spacecraft will be visible as we fly to Mars. Once we arrive we will slowly orbit the planet with a general Mars texture wrap/map, which will crossfade after about 30 seconds to both a high resolution Mars GIS map (lasting for approximately 30 seconds) and a high resolution Mars MOLA map (lasting for approximately 1.5 minutes). There will also be 3 still images that fade up at various orientations on the dome, showing examples of scientific data "collected" from the mission (these are images chosen from some actual Mars missions and are explained in more detail on pages 10-12). This mission is considered a success.

Clip M03d – Mars + Orbit + Nuclear: Same as Clip M03c, but using the spacecraft body without solar panels. This mission is considered a success.

Clip S03a – Saturn + Land + Solar: Take off Earth, view Earth from space. The spacecraft will be visible as we begin flying away to Saturn. At some point along the flight, the visuals will fade, then flicker, then become static. Low red lights will come on to signify failure/warning lights. This mission is considered a failure. It had insufficient power (too far from the Sun). Proceed to Clip 04 to discuss failure.

Clip S03b – Saturn + Land + Nuclear: Take off Earth, view Earth from space. The spacecraft will be visible as we begin flying away to Saturn. Once we arrive at Saturn, the lander will detach from the bigger craft and begin approaching the planet. This will crossfade to a view of the lander as it enters Saturn's atmosphere. After about 15 seconds, the outside of the lander will glow from atmospheric friction and will eventually disintegrate. This mission is considered a failure. It tried to land and burned up due to friction with the atmosphere. Proceed to Clip 04 to discuss failure.

Clip S03c – Saturn + Orbit + Solar: Take off Earth, view Earth from space. The spacecraft will be visible as we begin flying away to Saturn. At some point along the flight, the visuals will fade, then flicker, then become static. This mission is considered a failure. It had insufficient power (too far from the Sun). Proceed to Clip 04 to discuss failure.

Clip S03d – Saturn + Orbit + Nuclear: Take off Earth, view Earth from space. The spacecraft will be visible as we begin flying away to Saturn. Once we approach the planet, we will slowly orbit Saturn. Two still images will fade up at different orientations on the dome, showing examples of scientific data collected. (These are images chosen from the Cassini mission and are explained in more detail on pages 12 and 13). This mission is considered a success.

Clip 04 – Total mission failure: A series of still images of failed missions will come up in sequence against the blueprint background. After all the images are added, they will stay frozen in place on the dome until the entire video is faded down.

Interaction: This section is designed largely to be carried by the visuals. You can choose to either add music to accompany the visuals or to provide sporadic commentary when you feel it is appropriate. Once the video clip has ended, a good way to wrap up the activity is to ask them:

> *Do you think your mission succeeded in its goal? If not, what would you change?*
> *Can we learn anything if our mission fails?*
> *Based on the still images/data that you see, how do you see evidence of water?* (Possible answers: river channels, chemical data, pictures, minerals, samples)

If they succeed: Remind them that on a real space mission, engineers often have very complex decisions to make and lots of tests to run. They always have to be open to learning and considering all of the pros and cons of any situation. Congratulate them on their teamwork and decision-making and challenge them to think of other important decisions that might come up in the spacecraft design process after they leave the planetarium today.

If they fail: Remind them that engineers in real life, and certainly on a variety of space missions, have failed. Sometimes they catch the failures before the craft is in space, and sometimes the failures don't happen until the craft is in the middle of its mission. What is important is that even though they failed, there is still valuable information to be learned for the future, and more testing to do to ensure the success of future missions.

Images Used for Mission Success

Each successful mission results in still images intended to represent scientific data coming back from the audience's "mission." Each image is thought to be related to water in some way. At the end of the animation sequence showing success (i.e., landing on Mars, orbiting Saturn), these images will be brought up individually and left on the dome until the entire animation is faded down by the operator. Below is a description for each image.

Mars – LANDER success:

Image 1: "Blueberries"

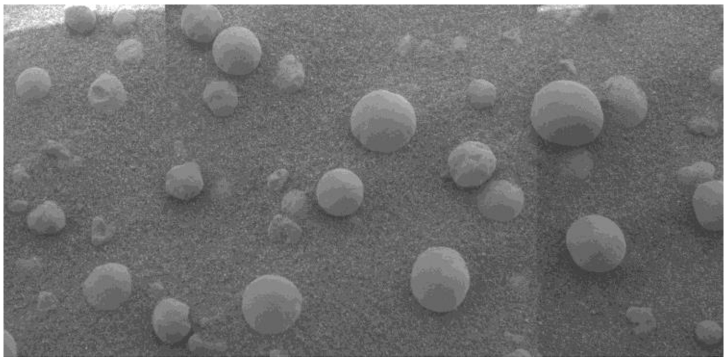


Image credit: NASA/JPL/Cornell/USGS

These round pebbles were discovered by the Opportunity rover near its landing site. Spectral imaging showed that the spheres were made primarily of hematite, and similar examples have been found on Earth (such as in southern Utah). The leading explanation for these hematite pebbles is that they were formed as minerals came out of solution after water passed through the surrounding rock, as this is what happens to form them on Earth. They are called "blueberries" because of their grey-blue hue and small round shape.

Image 2: Frost

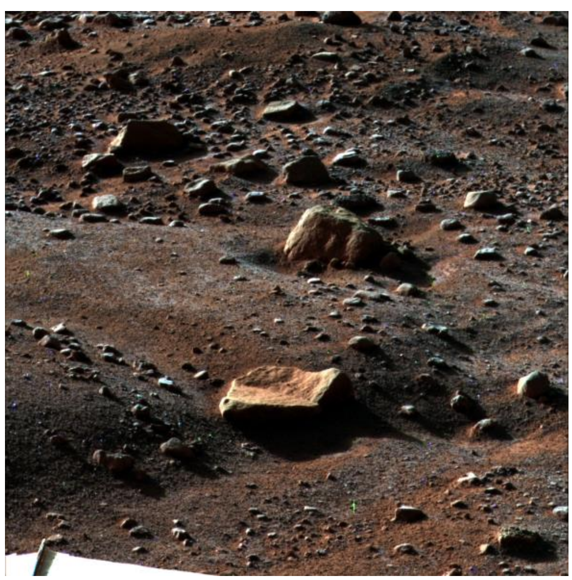


Image credit: NASA/JPL/Caltech/University of Arizona/Texas A&M University

This image was taken by the Mars Phoenix Lander just around sunrise. The bluish-white material clinging to the dust and some of the rocks was determined to be water frost. Subsequent images showed that the frost disappeared shortly after sunrise.

Image 3: Silica trench

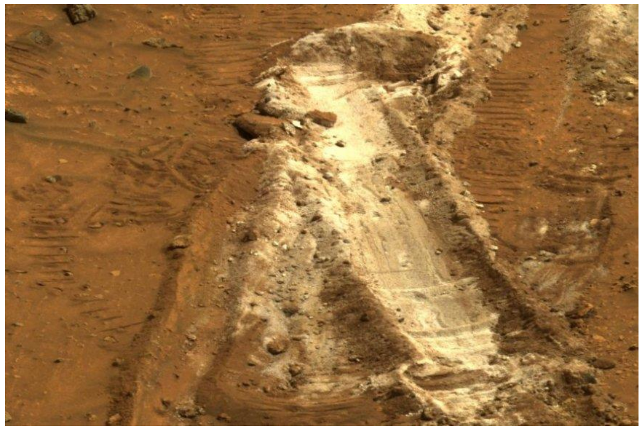


Image credit: NASA/JPL/Cornell

This image shows a trench dug by the jammed right front wheel on the Spirit rover. In a fortuitous accident, the rover was driving backwards and dragged this wheel along, exposing the white material under the dusty red surface. The Mini-TES (thermal emission spectrometer) on board the rover determined that the white material was almost pure silica. Deposits of pure silica like this can be found on Earth in locations such as the hydrothermal vents at Yellowstone. In those cases, the silica comes from hot water reacting with rocks.

Mars – ORBITER Success:

Image 1: River channel

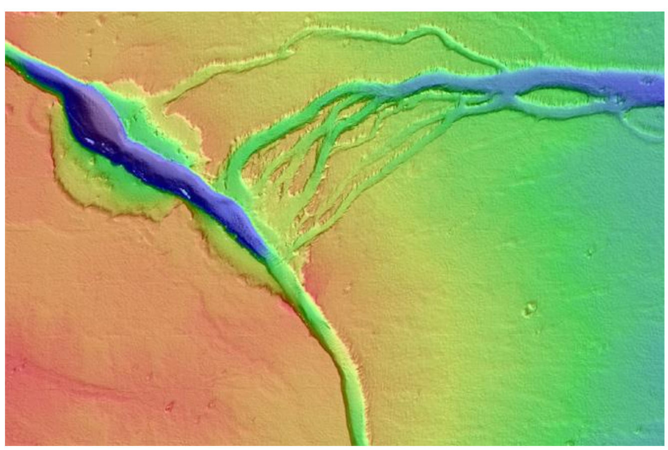


Image credit: NASA/JPL/University of Arizona/USGS

This image shows shaded relief of channels south of Ascraeus Mons – one of the three shield volcanoes southeast of Olympus Mons. In this image, blue is low elevation and red is higher elevation. The channels show similarities to river channels on Earth, with characteristics such as branching and braiding. They are not definitively carved by water, but that is one leading explanation for their formation.

Image 2: Gamma Ray Spectroscopy Data

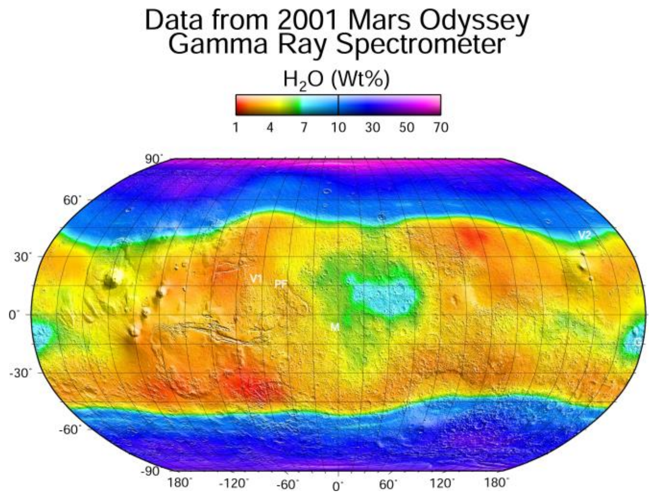


Image credit: NASA/JPL/University of Arizona

This image was created using data collected by the Gamma Ray Spectrometer (GRS) on board the 2001 Mars Odyssey orbiter. A GRS can measure the abundance and distribution of elements (such as hydrogen) on the surface. As a cosmic ray hits the surface, different elements emit a unique energy signature, which the GRS records. It can be thought of as a virtual shovel digging just below the surface. In this map from the GRS onboard Mars Odyssey, the abundance of hydrogen near the poles corresponds to high concentrations of water ice there. There are also a few equatorial concentrations of hydrogen, perhaps associated with subsurface water or ice. Note the concentration east of Valles Marineris, perhaps corresponding with a past outflow of water from that region.

Image 3: Rampart craters

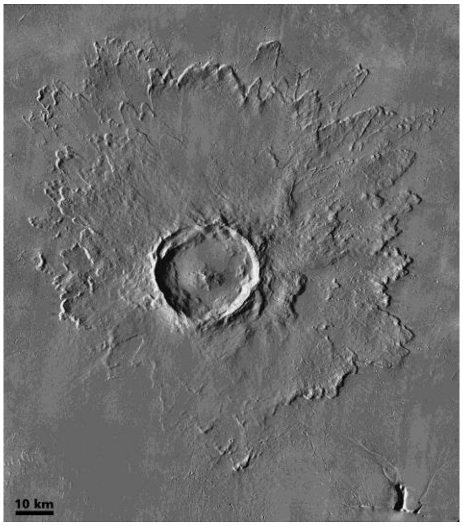


Image credit: NASA/JPL/Arizona State University

This image shows Tooting Crater on Mars, one of many interesting crater types called a “rampart” crater. Rampart craters have an appearance similar to splashed in mud puddles, and the ramparts are the ridges along the edges of the ejecta. Instead of following a traditional ballistic trajectory like most impact craters, rampart ejecta appears to flow across the ground from its point of origin. One leading theory about their formation is that the impactor penetrates to the level of ice or subsurface water, adding fluid to the ejecta.

Saturn – ORBITER Success:
Image 1: Geysers on Enceladus

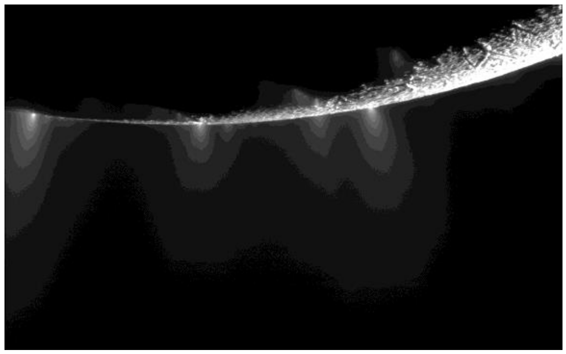


Image credit: NASA/JPL/Space Science Institute

This image shows geysers erupting from the south pole of Saturn’s moon, Enceladus. These geysers are shooting both water vapor and ice into space, and appear to be driven by small thermal hot spots. The water itself is coming from the subsurface liquid ocean confirmed to exist beneath Enceladus’ icy crust.

Image 2: E Ring of Saturn

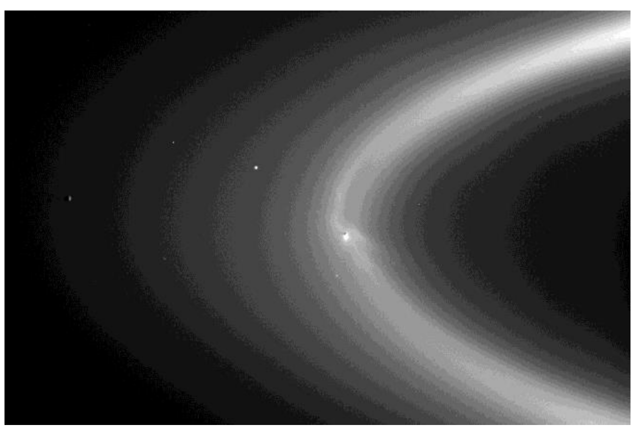
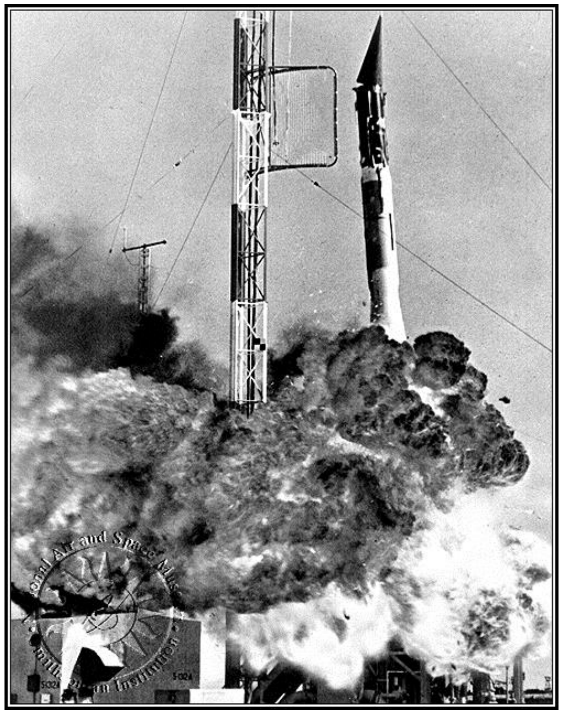


Image credit: NASA/JPL/Space Science Institute

This image shows how the moon Enceladus is firmly embedded in the E ring of Saturn and, most likely, is contributing to it with ice vapor.

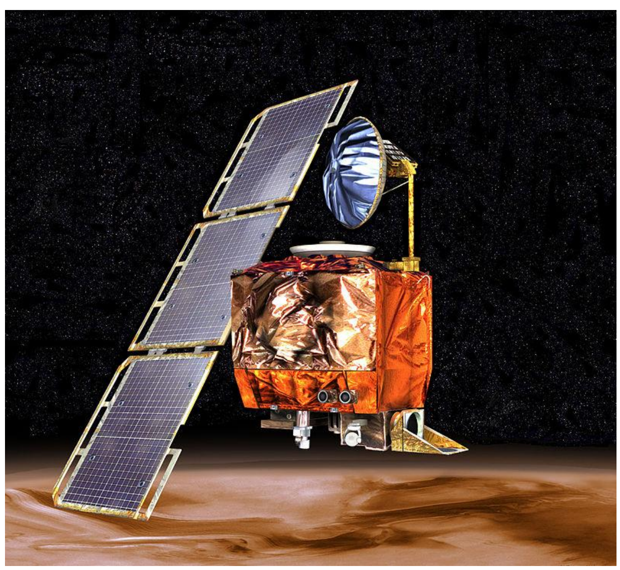
Images of Mission Failure

These images will come up as part of Clip 04.



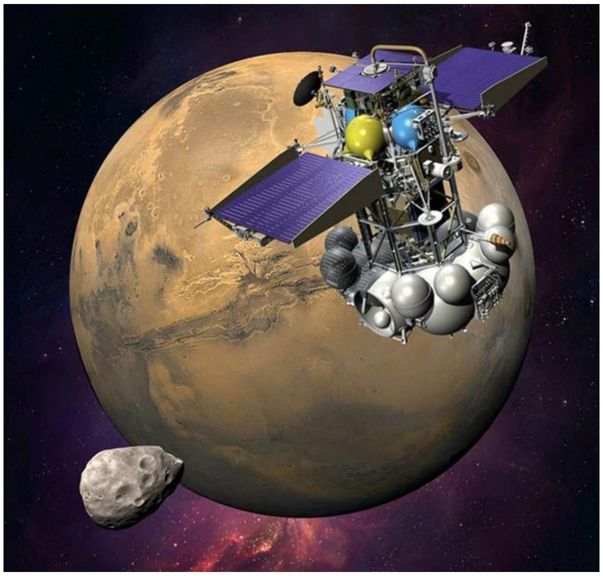
Vanguard TV-3 – Image credit: Smithsonian Institution/U.S. Navy

This was America's first attempt to launch a satellite into orbit. A few seconds after liftoff, the rocket lost thrust, fell back to the launch pad, and exploded.

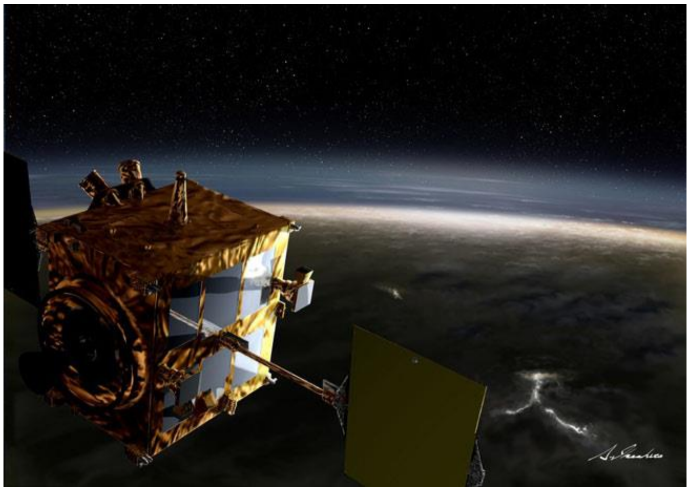


Mars Climate Orbiter – Image credit: NASA/JPL/Corby Waste

NASA mission to Mars. Engineers mixed up English and metric units, causing calculations to be incorrect. The satellite burned up in Mars' atmosphere.



Phobos-Grunt – Image credit: Russian Federal Space Agency/Roskosmos
Russian mission to the moons of Mars, designed to return samples to Earth. The spacecraft made it to Earth orbit, but its boosters didn't fire to take it out of orbit outwards toward Mars. Eventually the entire craft fell back to Earth.



Akatsuki – Image credit: Akihiro Ikeshita/JAXA
Akatsuki is a Japanese craft originally designed to orbit Venus starting in 2010. However, a main engine stopped firing during an insertion maneuver and Akatsuki missed its target. Since then, Japanese engineers have planned a few burns from small additional thrusters in an attempt to get the spacecraft back on track for a Venus encounter in 2015.

Video Clip List

Further descriptions of each clip can be found within the "Progression of the Activity" section.

Clip 00: Mars vs. Saturn

Clip 01: Lander vs. Orbiter

Clip 02a: Solar vs. Nuclear (with lander)
Clip 02b: Solar vs. Nuclear (with orbiter)

Clip M03a: Land + Solar + Mars
Clip M03b: Land + Nuclear + Mars
Clip M03c: Orbit + Solar + Mars
Clip M03d: Orbit + Nuclear + Mars

Clip S03a: Land + Solar + Saturn
Clip S03b: Land + Nuclear + Saturn
Clip S03c: Orbit + Solar + Saturn
Clip S03d: Orbit + Nuclear + Saturn

Clip 04: Mission Failure wrap up

Links to Outside Activities

Below are some useful links to background information and activities related to engineering design.

Build Your Own Space Mission
jpl.nasa.gov/education/BuildMissionGame.cfm
A simple app that allows you to drag and drop instruments onto a rover or lander and then choose from a few solar system locations to study. This activity is well-suited for most students, though may be best for grades 3-8.

The Edge of Sunshine
science.nasa.gov/science-news/science-at-nasa/2002/08jan_sunshine/
More information about how solar panels work in space.

The History of Nuclear Power in Space
energy.gov/articles/history-nuclear-power-space
Background on how nuclear generators on spacecraft work, as well as how they've been used through history.

Liftoff: Engineering Rockets and Rovers
eie.org/engineering-adventures/liftoff-engineering-rockets-and-rovers
A series of hands-on activities designed for afterschool programs, based on the real-world challenges of aerospace engineering.

Make a Mission
sciencenetlinks.com/interactives/messenger/makeAMission.swf
An interactive program to build a mission to Mercury, adding the intricate variables of cargo space and budget. Well-suited for older students with a concept of spatial organization and money management.